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Briggs

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(54) **SAMPLE VESSEL ASSEMBLY**

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G01N 35/00 (2006.01)
G01N 35/04 (2006.01)

(52) **U.S. Cl.**
CPC ***B01L 3/508*** (2013.01); ***G01N 35/00732*** (2013.01); *B01L 2200/025* (2013.01); *B01L 2200/026* (2013.01); *B01L 2300/041* (2013.01); *B01L 2300/046* (2013.01); *B01L 2300/0858* (2013.01); *G01N 2035/00277* (2013.01); *G01N 2035/00801* (2013.01); *G01N 2035/00831* (2013.01); *G01N 2035/00851* (2013.01); *G01N 2035/00881* (2013.01); *G01N 2035/0405* (2013.01); *Y10T 436/11* (2015.01)

(58) **Field of Classification Search**
CPC B01L 3/508; B01L 3/52; B65D 5/001; B65D 5/005; B65D 5/002
USPC 422/551, 554; 206/501; 220/781, 380, 220/4.26
See application file for complete search history.

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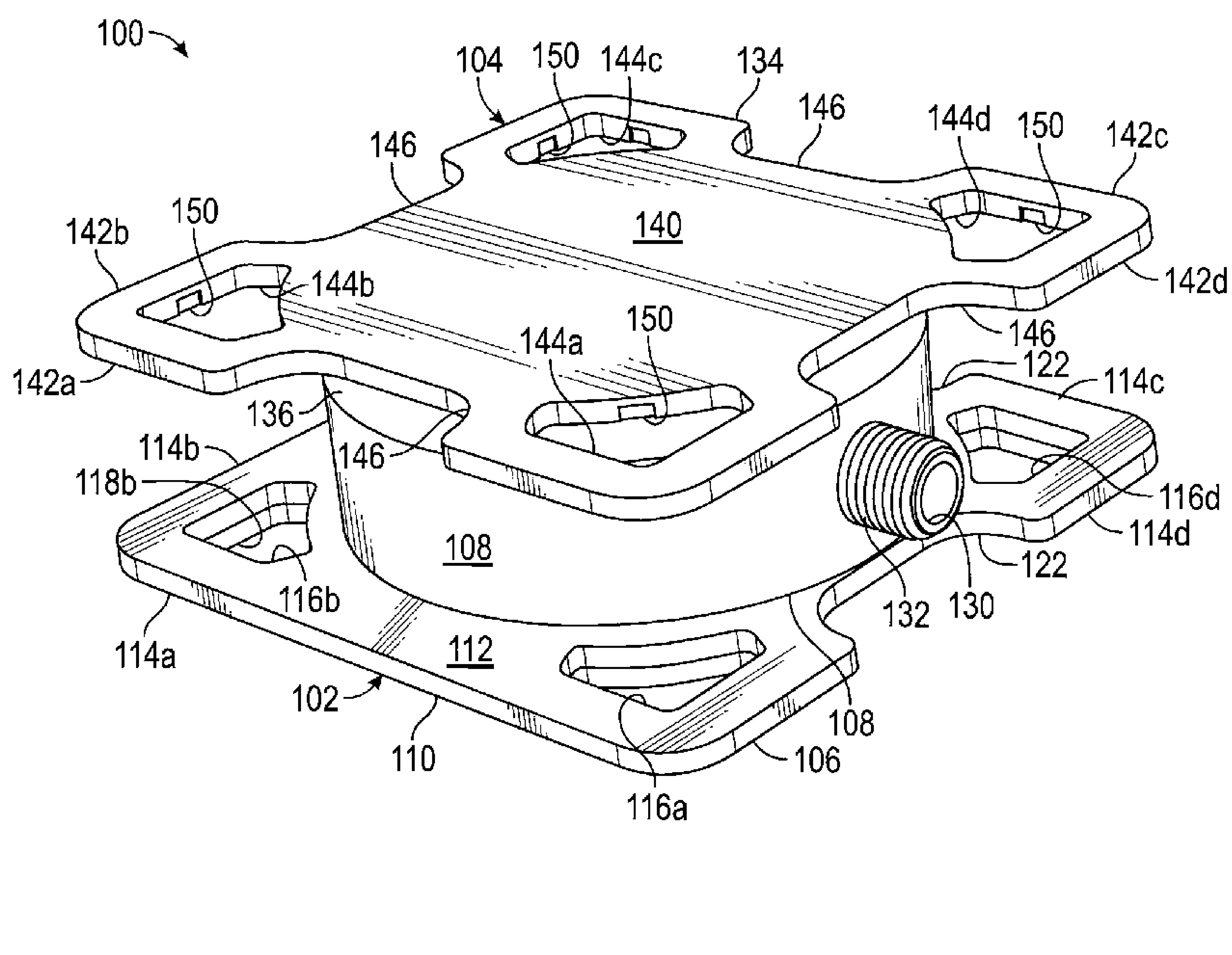
(74) *Attorney, Agent, or Firm* — Dunlap Codding, P.C.

(57) **ABSTRACT**

A sample vessel assembly, comprising a base member including a base flange having first and second opposing surfaces, first and second sides intersecting with one another; and a first sidewall extending from the first surface at a distance from the first and second sides; and a lid member, including: a lid flange having third and fourth opposing surfaces, third and fourth sides intersecting with one another; and a second sidewall extending from the third surface at a distance from the third and fourth sides, the second sidewall engageable with the first sidewall such that the first surface of the base flange and the third surface of the lid flange are in an opposing spaced-apart relationship with one another and such that the first and second sidewalls cooperate with one another to define a sample chamber. Further disclosed is a method for automated analysis of samples in a sample vessel assembly.

11 Claims, 8 Drawing Sheets



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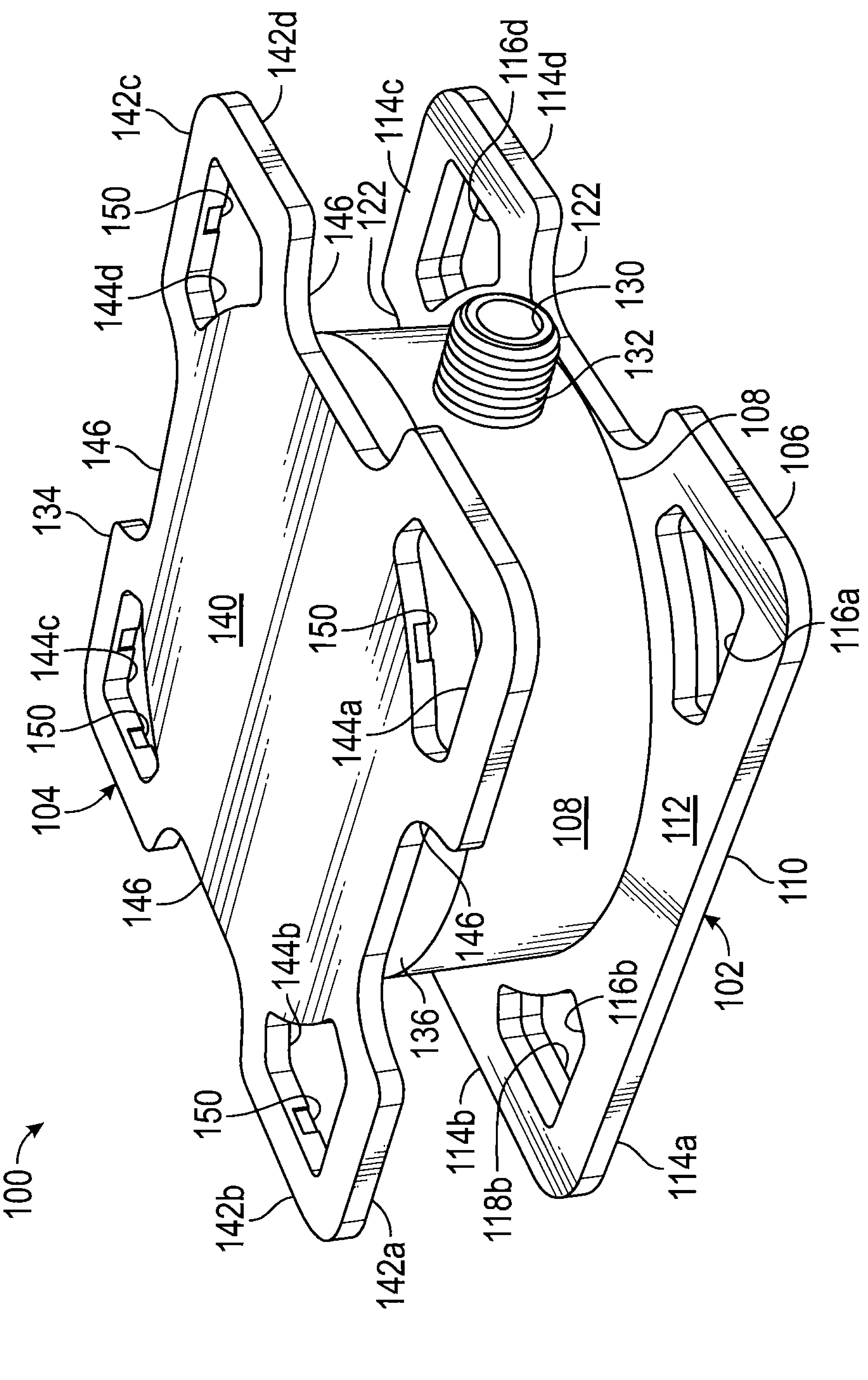
100
102
104
106
108
110
112
114a
114b
114c
114d
116a
116b
116d
118b
122
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142a
142b
142c
142d
144a
144b
144c
144d
146
150

FIG. 1

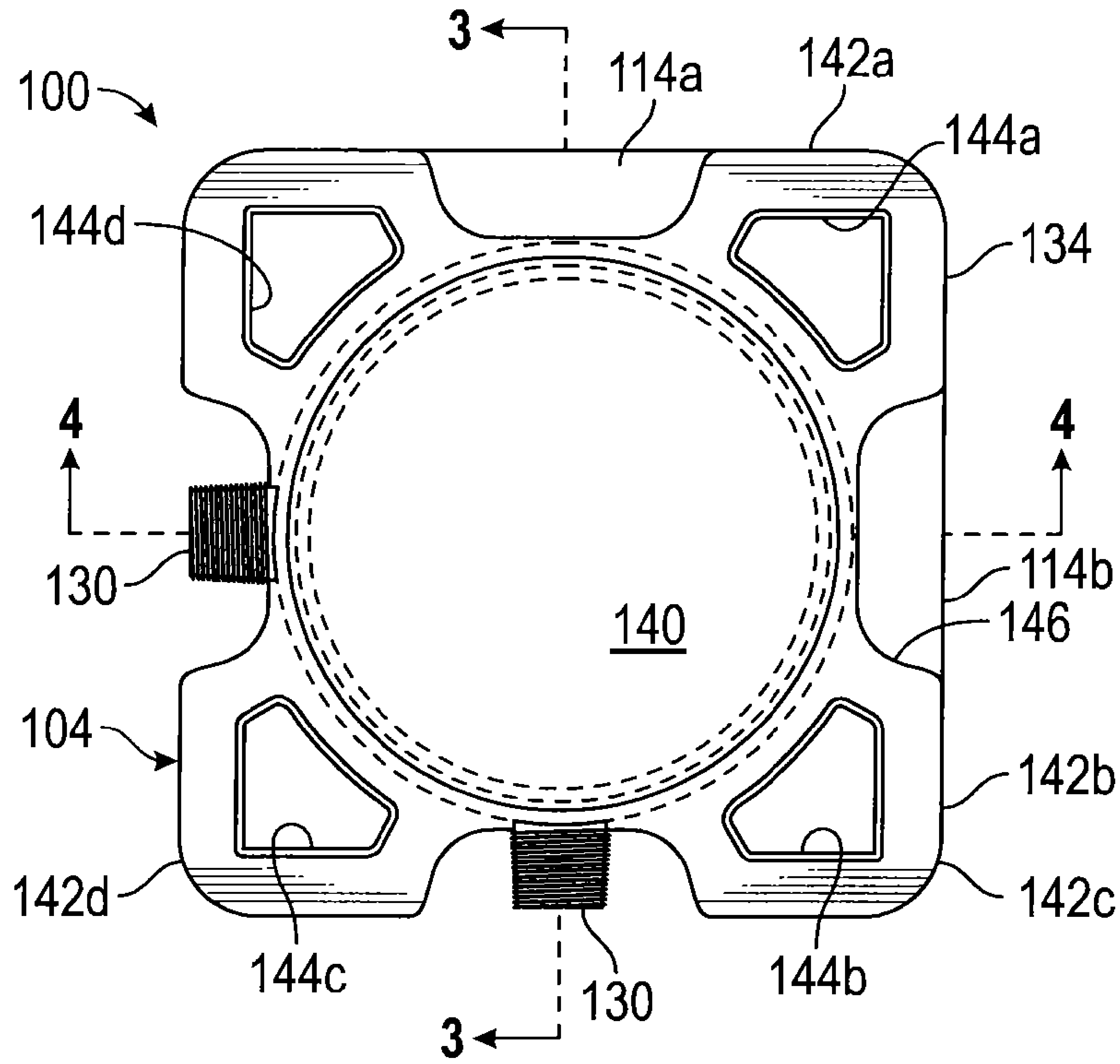


FIG. 2

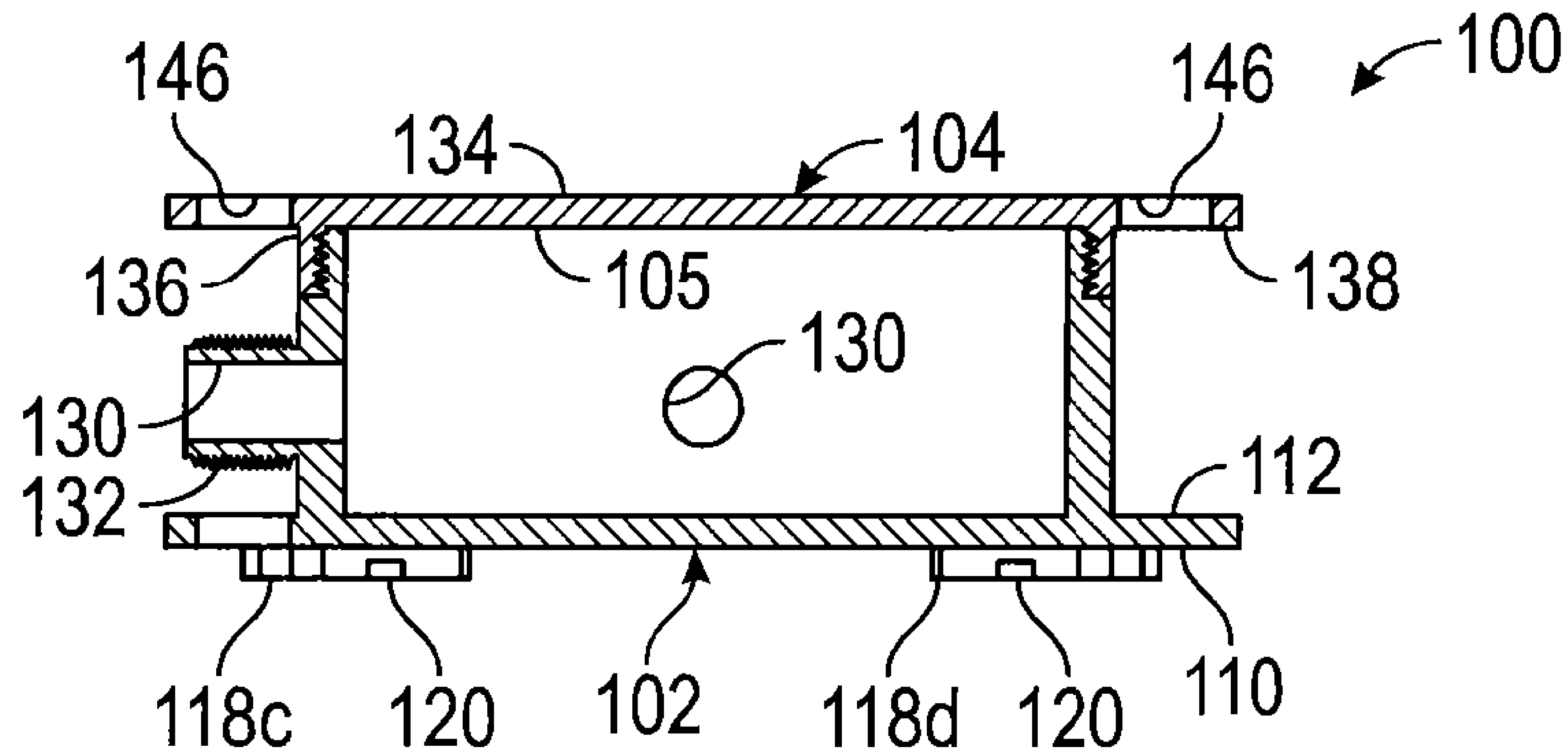


FIG. 3

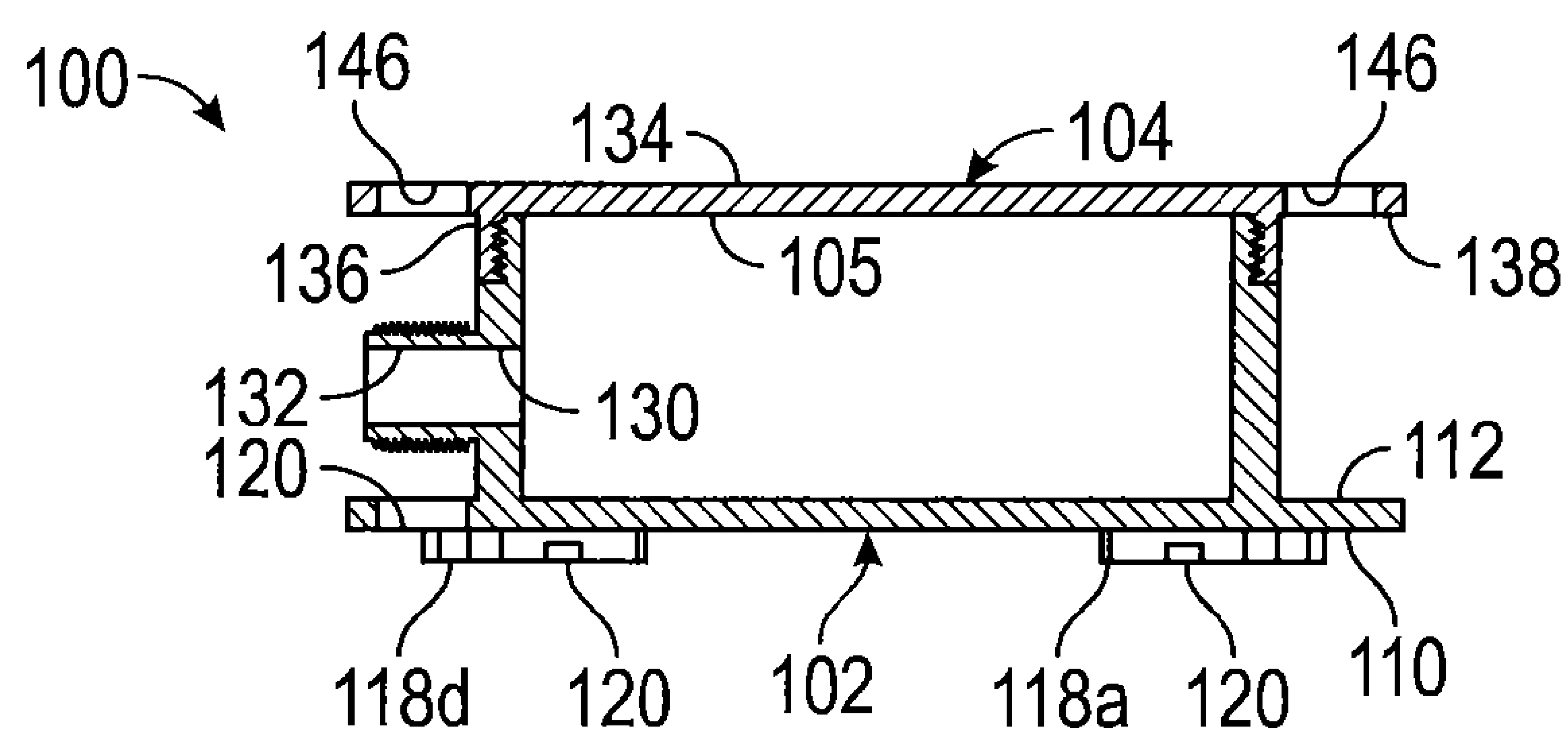


FIG. 4

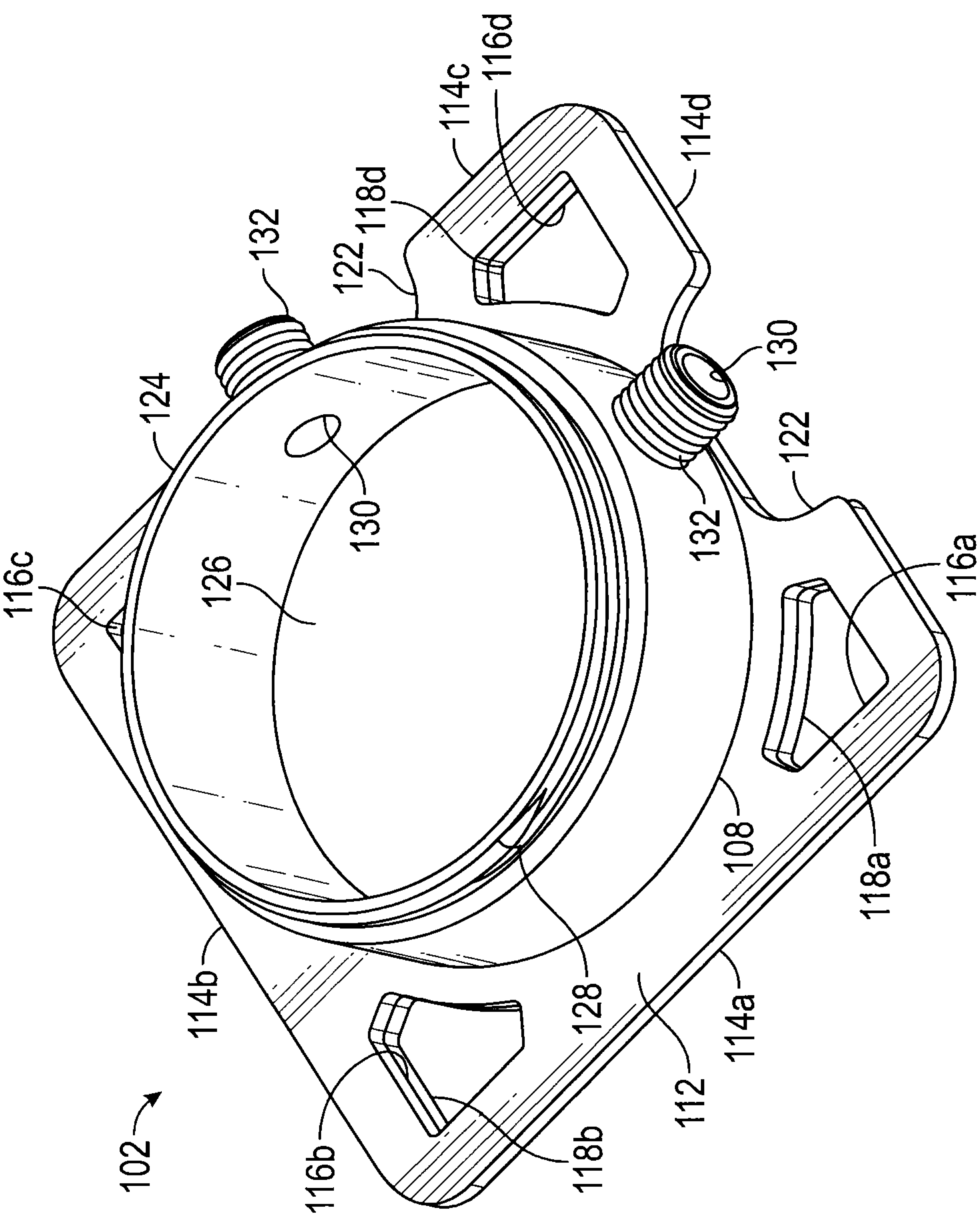
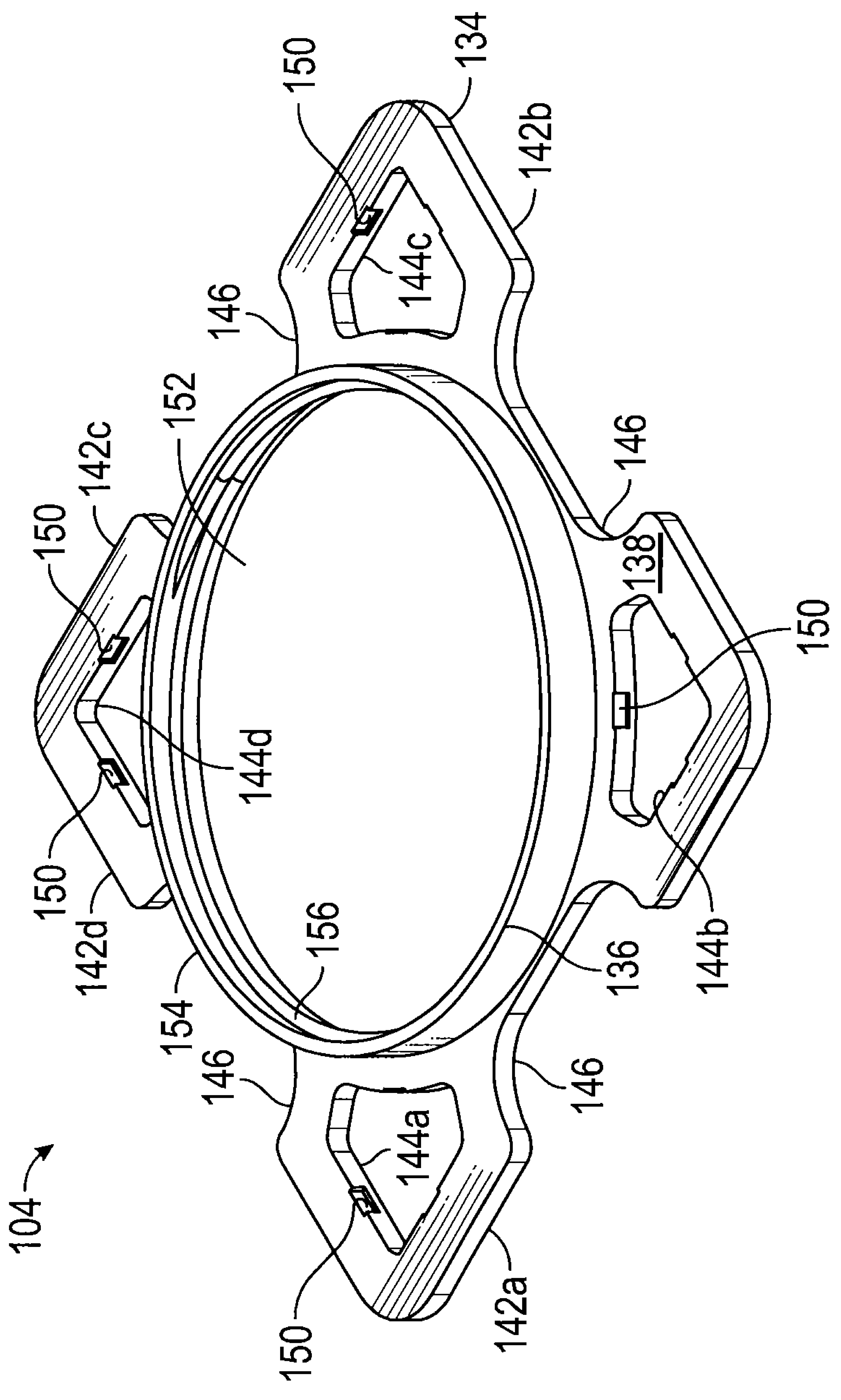

102
114b
116b
118b
112
114a
128
108
118a
116a
122
132
130
126
116c
124
130
132
122
118d
114c
116d
114d

FIG. 5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142b
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144c
146
152
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144d
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142d
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146
144a
150
142a

FIG. 6

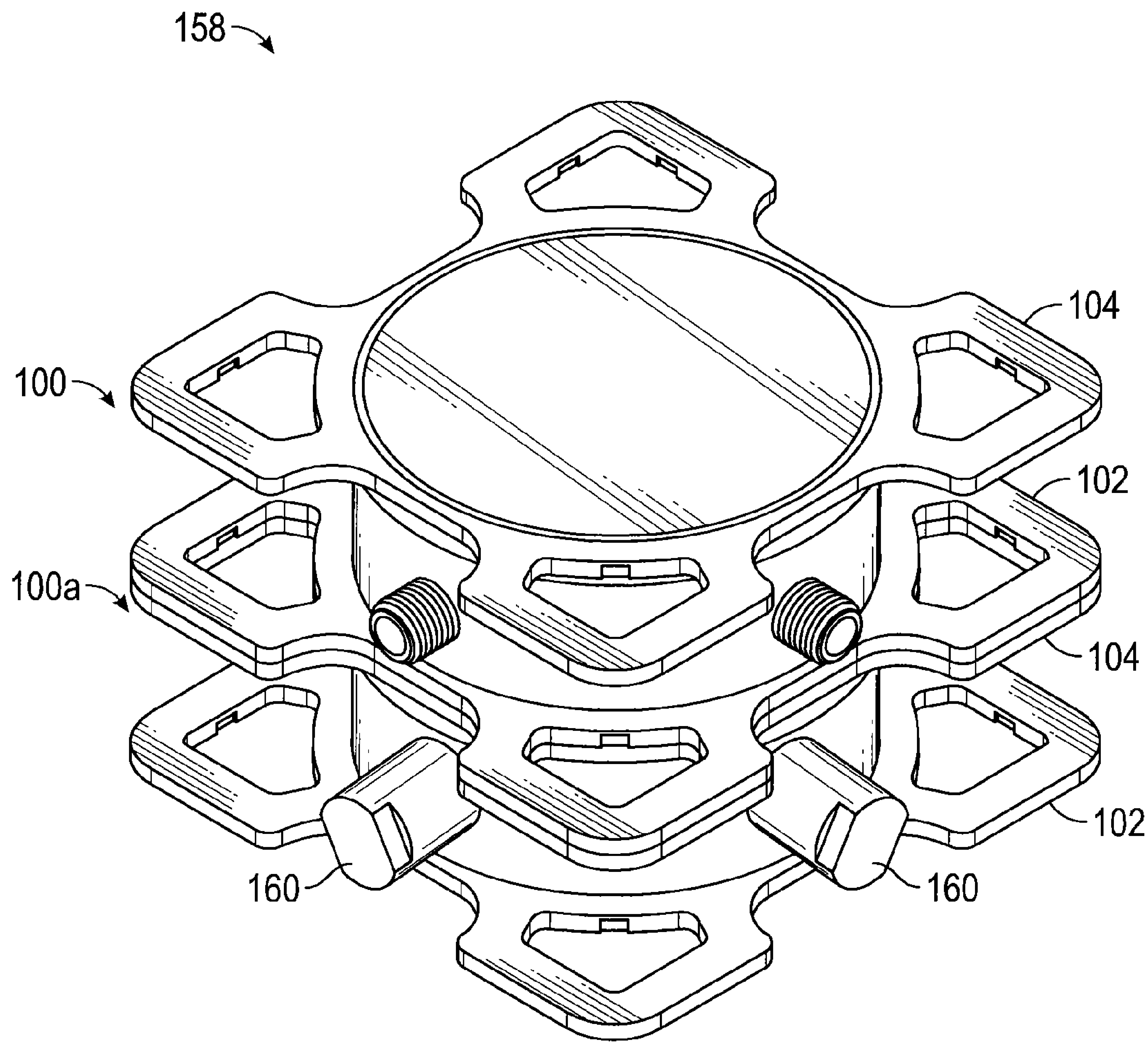


FIG. 7

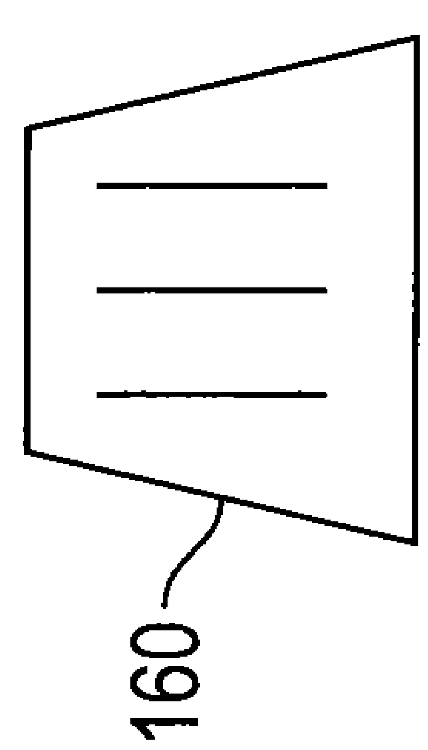


FIG. 8A

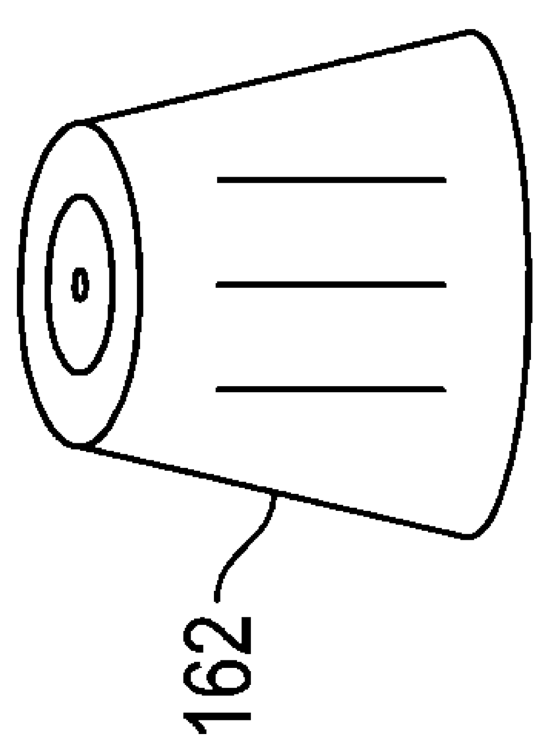


FIG. 8B

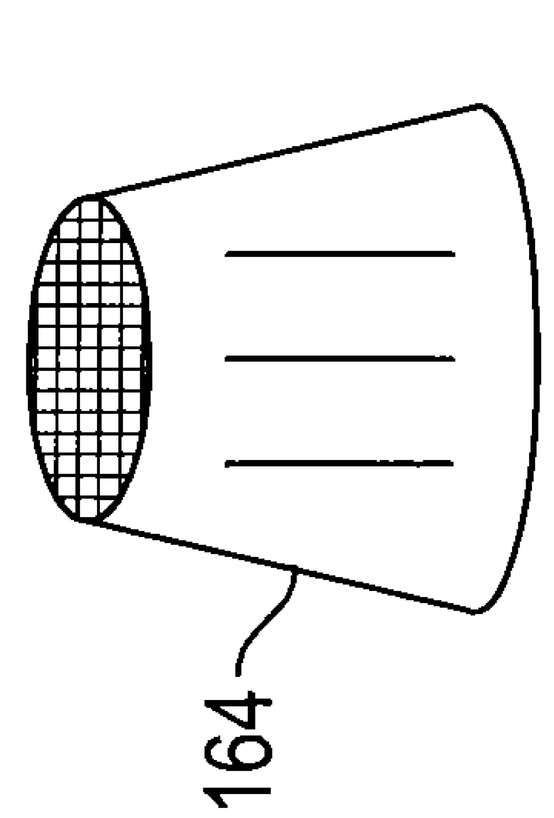


FIG. 8C

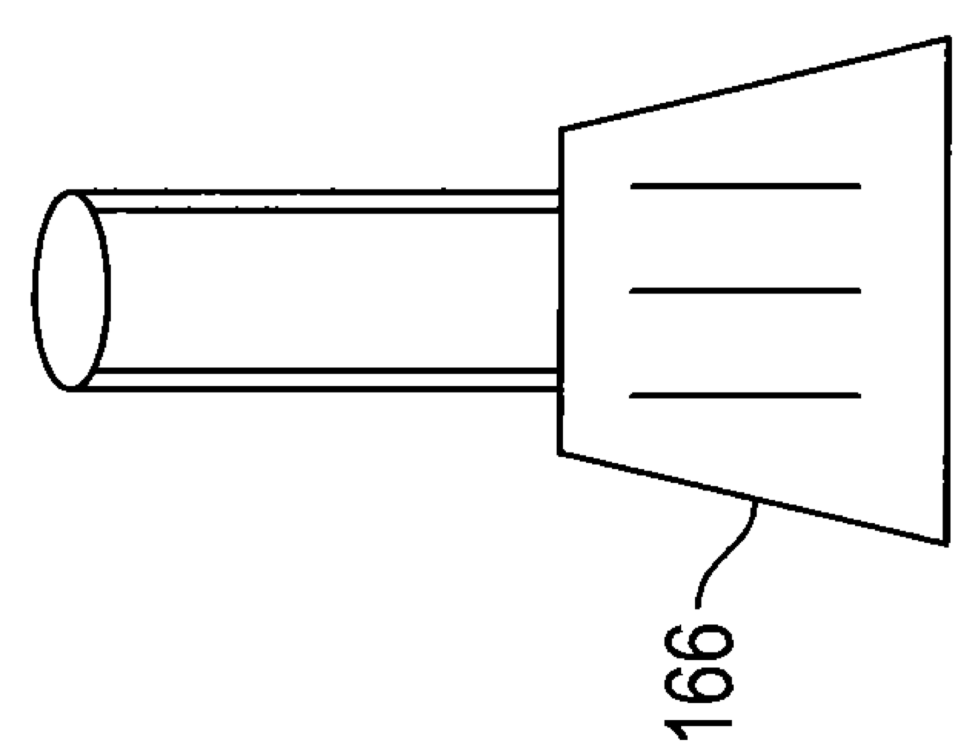


FIG. 8D

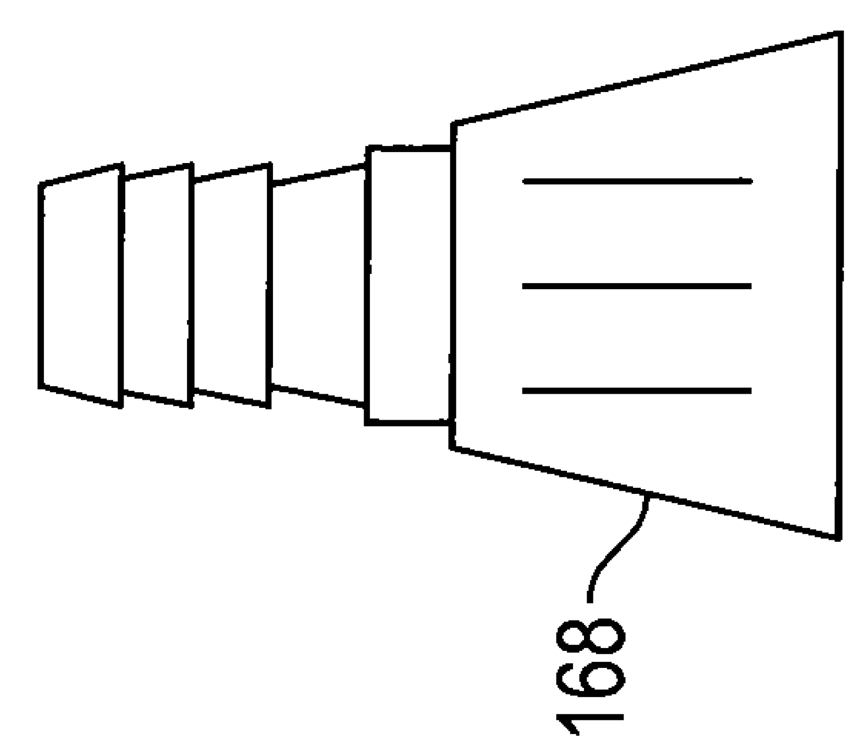


FIG. 8E

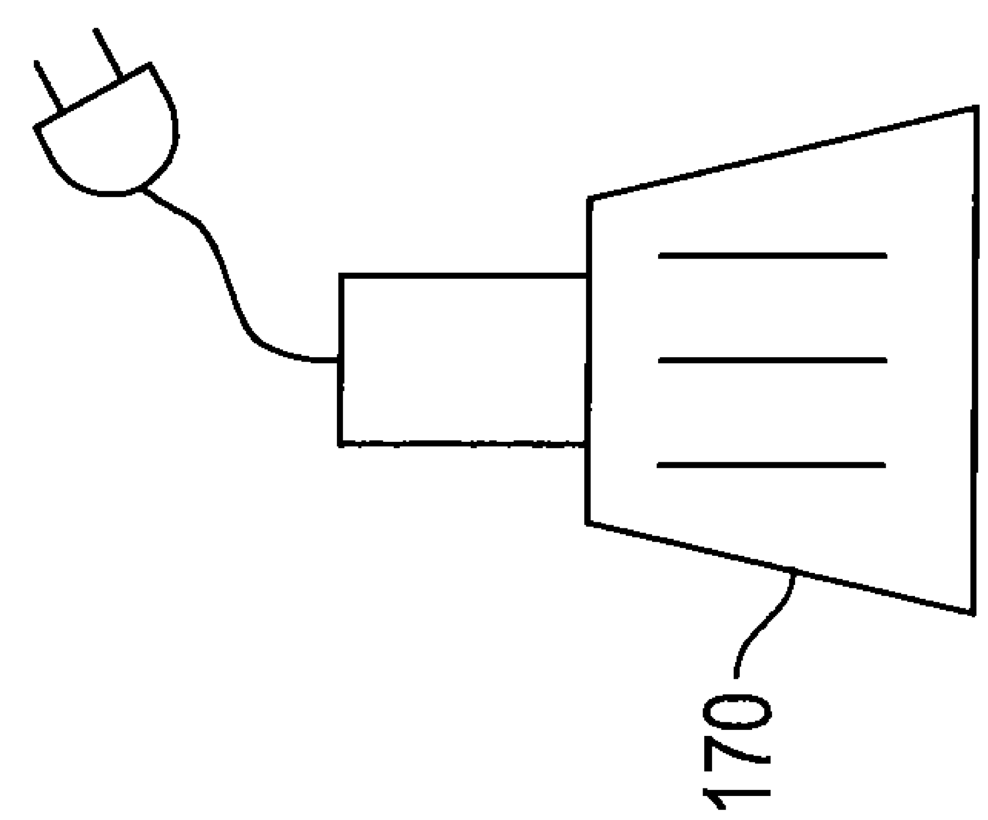
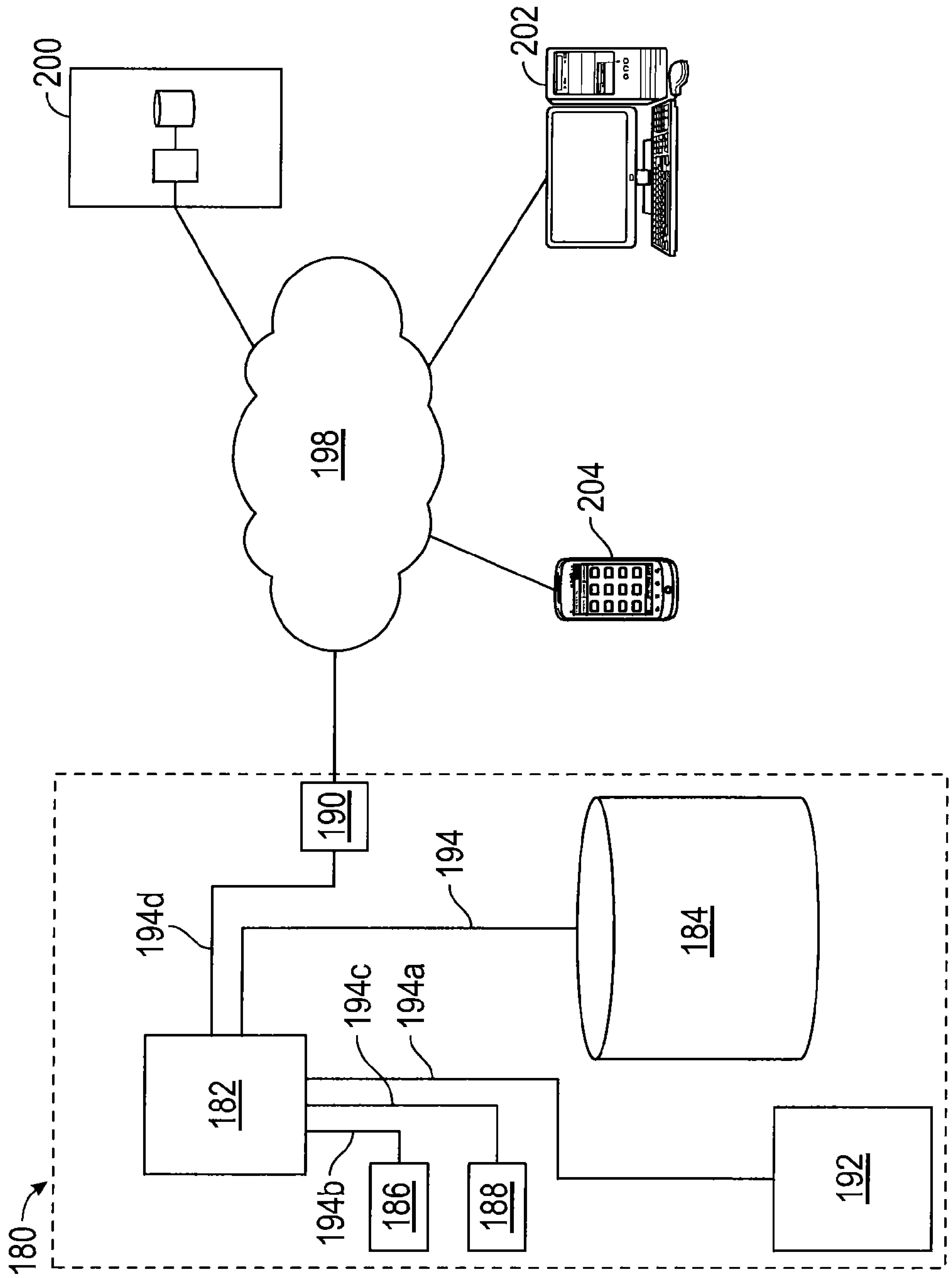


FIG. 8F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194d
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194c
194a
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194b
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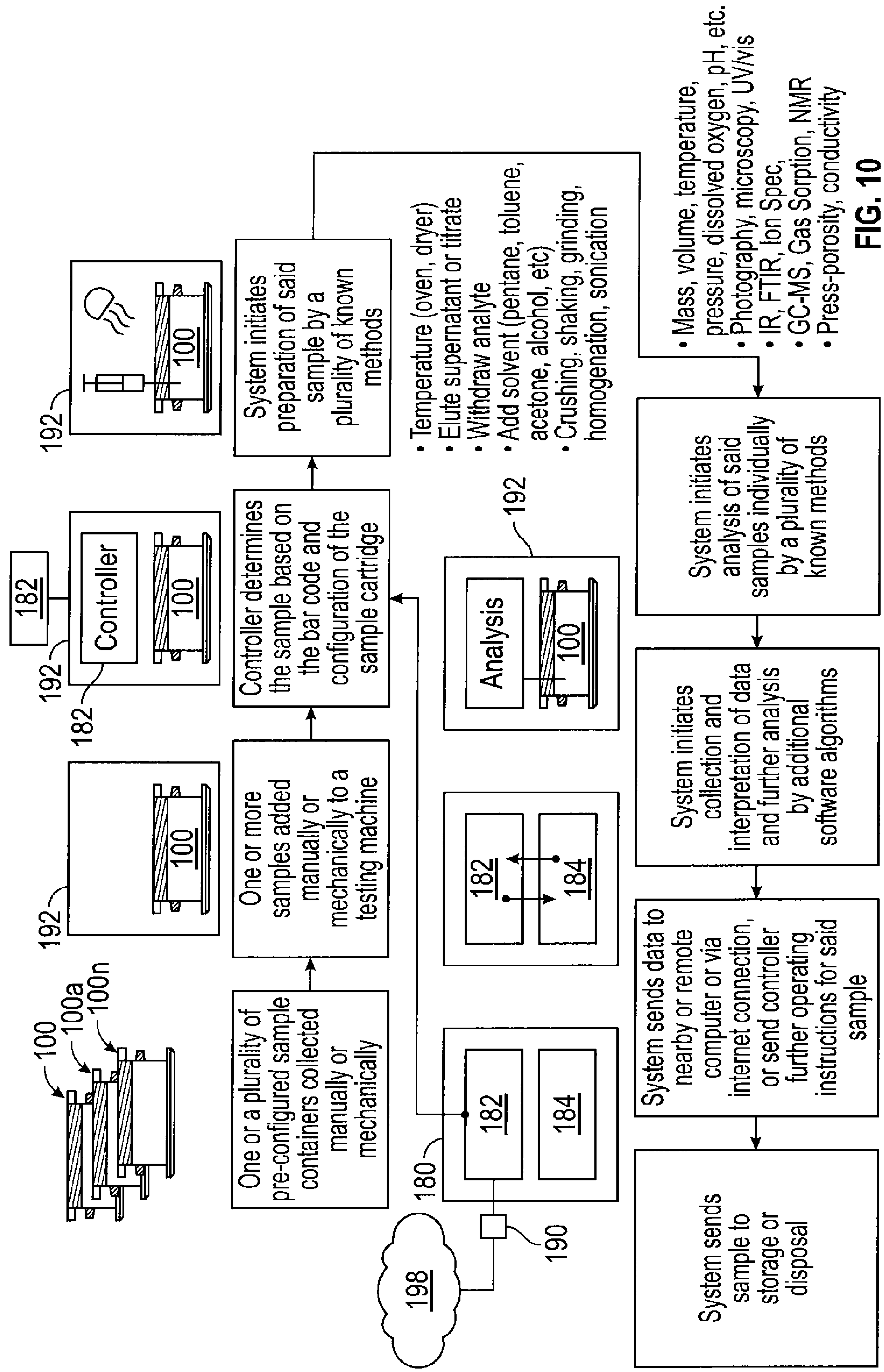
192

FIG. 9



100
100a
100n
One or a plurality of pre-configured sample containers collected manually or mechanically
192
100
One or more samples added manually or mechanically to a testing machine
182
192
182
Controller
100
Controller determines the sample based on the bar code and configuration of the sample cartridge
192
100
System initiates preparation of said sample by a plurality of known methods
• Temperature (oven, dryer)
• Elute supernatant or titrate
• Withdraw analyte
• Add solvent (pentane, toluene, acetone, alcohol, etc)
• Crushing, shaking, grinding, homogenation, sonication
198
190
180
182
184
182
184
192
Analysis
100
• Mass, volume, temperature, pressure, dissolved oxygen, pH, etc.
• Photography, microscopy, UV/vis
• IR, FTIR, Ion Spec,
• GC-MS, Gas Sorption, NMR
• Press-porosity, conductivity
System initiates analysis of said samples individually by a plurality of known methods
System initiates collection and interpretation of data and further analysis by additional software algorithms
System sends data to nearby or remote computer or via internet connection, or send controller further operating instructions for said sample
System sends sample to storage or disposal

FIG. 10

SAMPLE VESSEL ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Ser. No. 61/950,510, filed on Mar. 10, 2014, the entire content of which is hereby expressly incorporated herein by reference.

BACKGROUND

Many fields and industries require the capture, storage, and analysis of various samples. For example, life sciences and related diagnostic and laboratory testing fields capture, store, and analyze various fluids, such as blood. The environment in which the samples are collected and analyzed is carefully controlled to avoid contamination of the sample, and the volume of the sample required to carry out the desired analysis is generally low. As such, open ended, low volume sample vessels, such as test tubes, have long been used to capture, store, and analyze samples of this type.

Other industries, such as the petrochemical industry, also require the capture, storage, and analysis of various samples. For example, during the process of drilling oil and gas wells, it is desirable to collect and analyze drilling fluids and drill cuttings. Unlike a laboratory setting, the environment at a well site, where drilling fluid and drill cutting samples must be collected, is harsh. Furthermore, the volume of the samples required to carry out the desired analysis can be relatively large.

Some existing sampling and analytical technology allows for using automation and increasing throughput of low volume samples. In some cases, where relatively larger volume samples are used, well plates and test tubes have been implemented to collect and/or analyze such large-volume samples. However, test tubes, well plates, or cuvettes are generally fragile, have a single access point usually through the top, and are not easy to transport, process, and store in non-delicate sampling environments. Further, existing test tubes allow limited sample size and are sub-optimal for mixed-phase samples such as soil, silt, mud, drilling fluids, or other mixed-phase samples. Finally, while existing test tubes or plates allow for simple testing of samples, it can be difficult to reliably and consistently image samples positioned inside existing test tubes or plates.

Accordingly, a need exists for a sample vessel assembly which has a relatively large volume and which is configured to be used with mixed-phase samples. It is to such a sample vessel assembly and to methods of using same in automated analysis systems that the inventive concepts disclosed herein are directed.

BRIEF DESCRIPTION OF THE DRAWINGS

Implementations of the inventive concepts disclosed herein may be better understood when consideration is given to the following detailed description thereof. Such description makes reference to the annexed pictorial illustrations, schematics, graphs, figures, or drawings. The drawings are not necessarily to scale, and certain features and certain views of the drawings may be shown exaggerated, to scale, or in schematic in the interest of clarity and conciseness. Like reference numerals in the figures may represent and refer to the same or similar element or function. In the drawings:

FIG. **1** is a perspective view of an embodiment of a sample vessel assembly according to the inventive concepts disclosed herein.

FIG. **2** is a top plan view of the sample vessel assembly of FIG. **1**.

FIG. **3** is a cross-sectional view along line **3-3** of FIG. **2**.

FIG. **4** is a cross-sectional view along line **4-4** of FIG. **2**.

FIG. **5** is a perspective view of an embodiment of a base member according to the inventive concepts disclosed herein.

FIG. **6** is a perspective view of an embodiment of a lid member according to the inventive concepts disclosed herein.

FIG. **7** is a perspective view of a stack of sample vessel assemblies according to the inventive concepts disclosed herein.

FIGS. **8**A-**8**F show exemplary embodiments of couplings for a port of a sample vessel assembly according to the inventive concepts disclosed herein.

FIG. **9** is a diagram of an exemplary embodiment of an automated analysis system configured to be implemented with sample vessel assemblies according to the inventive concepts disclosed herein.

FIG. **10** is a diagram of a process of using a sample vessel assembly according to the inventive concepts disclosed herein with an automated analyzer system.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Before describing embodiments of the inventive concepts disclosed herein in detail, it is to be understood that the inventive concepts are not limited in their application to the details of construction and the arrangement of the components or steps or methodologies set forth in the following description or illustrated in the drawings. The inventive concepts disclosed herein are capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting the inventive concepts disclosed and claimed herein in any way.

In the following detailed description of embodiments of the inventive concepts, numerous specific details are set forth in order to provide a more thorough understanding of the inventive concepts. However, it will be apparent to one of ordinary skill in the art that the inventive concepts within the disclosure may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the instant disclosure.

As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having,” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherently present therein.

As used herein the notation “a-n” appended to a reference numeral is intended as merely convenient shorthand to reference one, or more than one, and up to infinity, of the element or feature identified by the respective reference numeral (e.g., **134**_a-n_). Similarly, a letter following a reference numeral is intended to reference an embodiment of the feature or element that may be similar, but not necessarily identical, to a previously described element or feature bearing the same reference numeral (e.g., **148**, **148**_a_, **148**_b_, etc.).

Such shorthand notations are used for purposes of clarity and convenience only, and should not be construed to limit the instant inventive concepts in any way, unless expressly stated to the contrary.

Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by anyone of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

In addition, use of the "a" or "an" are employed to describe elements and components of the embodiments herein. This is done merely for convenience and to give a general sense of the inventive concepts. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

As used herein "mixed-phase media," and "mixed-phase sample" are intended to include a sample or media including two or more of the following phases of one or more materials: a solid phase, a fluid phase, a liquid phase, a vapor phase, and a gas phase.

Finally, as used herein any reference to "one embodiment" or "an embodiment" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment, and the inventive concept, and the inventive concepts disclosed herein are intended to encompass any and all combinations, subcombinations, and permutations including one or more of the features described or inherently present herein and/or obvious variations thereof.

The inventive concepts disclosed herein are generally directed to sample vessel assemblies and to methods of using same. In some embodiments, sample vessel assemblies according to the inventive concepts disclosed herein may be implemented as large-volume sample vessel assemblies for mixed-phase samples where non-delicate obtaining, handling, or storage of such samples is to be carried out. Further, in exemplary embodiments, sample vessel assemblies according to the inventive concepts disclosed herein may be configured for use as sample cartridges for automated analysis systems. Sample vessel assemblies according to the inventive concepts disclosed herein facilitate sample characterization and analysis by enabling "in-vessel" analysis, reducing contamination, protecting field and laboratory personnel from volatiles or pathogens in samples, allowing "breaking down" of samples to sub-samples or aliquots for various types of distinct testing, enabling automation and high throughput screening, and allowing integration with existing automated analysis systems and methods.

Sample vessel assemblies according to some embodiments of the inventive concepts disclosed herein are modular, and may be configurable for specific analyses and processes. For instance, sample vessel assemblies according to the inventive concepts disclosed herein may be used manually on a bench-top, or may be geared toward automation via automated analysis systems. Further, embodiments of sample vessel assemblies according to the inventive concepts disclosed herein may include optional shaped sides, openings, protrusions, stubs, or other structures for handling, grabbing, stacking, or interlocking or stacking of sample vessel assemblies. Additionally, some embodiments include superstructures configured to allow for easy opening, grabbing and automation from any orientation of the sample vessel assembly, and such superstructures may be triangular, oval, rectangular, square, trapezoid, polygonal, star-shaped, or combinations thereof.

Embodiments of the inventive concepts disclosed herein may be implemented with various ports, couplings, or valves positioned at various locations for sample collection, characterization, and analysis. Further, some embodiments of sample vessel assemblies may be substantially opaque to protect samples from UV or other light damage, or may include one or more transparent portions to allow visual inspection of samples in the sample vessel assembly such as by a spectrophotometer, a spectrometer (e.g., IR), a microscope, or any other desired optical instrument. In addition, embodiments of sample vessel assemblies may be configured for varying containment levels, such as being substantially impermeable to fluids, gasses, air, pressure-rated for any desired pressure, temperature-rated for any desired temperature, or combinations thereof, for example, depending on sample-type and/or desired test or analysis methods.

Referring now to FIGS. **1-6**, shown therein is a sample vessel assembly **100** according to an embodiment of the inventive concepts disclosed herein. The sample vessel assembly **100** includes a base member **102** and a lid member **104** configured to be coupled or otherwise engaged with one another so as to define a substantially fluidly-impermeable sample chamber **105** (FIGS. **3-4**).

The base member **102** includes a base flange **106** and a sidewall **108**. The base member **102** may be constructed of any desired material such as metals, alloys, non-metals, polymers, glass, ceramic materials, composite materials, plastics, resins, carbon fiber, or combinations thereof, and may be manufactured by any desired method or process such as molding, machining, die cutting, casting, 3D-printing, or combinations thereof. In some embodiments, the base member **102** may be substantially opaque or may include a transparent surface or portion so as to allow visual inspection and/or optical instrument measurements of a sample placed in the sample vessel assembly **100** as will be appreciated by persons of ordinary skill in the art having the benefit of the instant disclosure.

The base flange **106** has opposing surfaces **110** and **112** and sides **114***a-d*. The surfaces **110** and **112** include openings **116***a-d*, and attachment protrusions **118***a-d*. The surfaces **110** and **112** are shown as being substantially flat, although in some embodiments one or both of the surfaces **110** and **112** may include one or more curved (e.g., concave or convex) portions, raised, roughened or textured portions, one or more label portions, one or more bar code or QR code portions, one or more color coded portions, one or more handle or gripping portions, and combinations thereof. Further, in some embodiments, one or both surfaces **110** and **112** may include optional color-coding or other visual or haptic markings indicative of directional orientation of the base member **102**, volume of the sample vessel assembly **100**, pressure rating of the sample vessel assembly **100**, date of manufacture, or any other desired information, as will be appreciated by persons of ordinary skill in the art having the benefit of the instant disclosure.

The openings **116***a-d* may be formed in the base flange **106** in any desired manner, and may extend completely or partially from the surface **110** to the surface **112**. The openings **116***a-d* may be configured to function as handles or grasping portions so as to allow a user or a robotic arm to securely grasp and/or manipulate the base flange **106**. It is to be understood that the openings **116***a-d* may have any desired shape and size. Further, in some embodiments the openings **116***a-d* may be omitted, and in some embodiments any desired number of openings **116***a-d* may be implemented, such as one, two, three, or more than four openings **116***a-n*. The openings **116***a-d* are shown as being offset from the sides **114***a-d*, but it is to be understood that in some embodiments the openings **116***a-d* may intersect with the sides **114***a-d*.

The attachment protrusions **118***a-d* are shown as extending from the surface **110** adjacent to the openings **116***a-n*. The attachment protrusions **118***a-n* include lateral portions **120** sized and configured to be matingly received in corresponding attachment notches formed in the lid flange **104** as described below. It is to be appreciated that any desired number of attachment protrusions **118***a-n* may be implemented with the inventive concepts disclosed herein. Further, in some embodiments the attachment protrusions **118***a-d* may be omitted.

The sides **114***a* and **114***b* are shown as being substantially straight, and the sides **114***c* and **114***d* are shown as including notches **122** formed therein. It is to be understood that in some embodiments the notches **122** may be omitted, and in some embodiments the sides **114***a* and **114***b* may include one or more notches **116** formed therein. The notches **122** may be configured to allow easier access to the sample inside the sample chamber from the direction of the base member **102**. Further, the sides **114***a-d* may have any desired shape, curvature, or profile, including being concave, convex, angled, or including one or more portions having different curvature or profile, as will be appreciated by a person of ordinary skill in the art having the benefit of the instant disclosure.

It is to be appreciated that while the four sides **114***a-d* are shown as intersecting with one another to define a substantially square superstructure of the base flange **106**, base flanges **106** according to the inventive concepts disclosed herein may have any desired numbers of sides **114***a-n*, such as one, two, three, five, six, seven, or more than seven sides **114***a-n*. Further, base flanges **106** according to the inventive concepts disclosed herein may have any desired shapes or superstructures, such as circular, oval, triangular, rectangular, trapezoid, pentagonal, hexagonal, heptagonal, octagonal, polygonal, star-shaped, irregularly-shaped, or combinations thereof.

The sidewall **108** extends from the surface **112** such that the sidewall **108** is separated at a distance from the sides **114***a-d* and/or the openings **116***a-d*, and such that the openings **116***a-d* are positioned between the sidewall **108** and the sides **114***a-d*. However, in some embodiments the sidewall **108** may abut or intersect with one or more of the openings **116***a-d*, and/or may abut or intersect with one or more of the sides **114***a-d*. The sidewall **108** may be attached to the surface **112** in any desired fluidly-impermeable manner, such as via welding, joints, seams, or adhesives, or combinations thereof. In some embodiments, the sidewall **108** and the base flange **106** may be formed as a unitary body, such as via casting, machining, molding, or 3D printing, for example. While the sidewall **108** is shown as being substantially centered relative to the surface **112**, in some embodiments the sidewall **108** may be offset relative to the surface **112**, such that the sidewall **108** is separated at a first distance from one of the sides **114***a-d*, and a second distance different from the first distance from another one of the sides **114***a-d*.

The sidewall **108** is shown as being substantially circular, however, embodiments of a sidewall **108** according to the inventive concepts disclosed herein may be implemented with any desired shape, curvature, or cross-sections, such as oval, circular, triangular, rectangular, square, polygonal, or combinations thereof. The sidewall **108** includes an end **124** extending at any desired distance from the surface **112**, and a bottom **126** which may be substantially flat, or may have any desired curvature (e.g., concave or convex) in some embodiments, depending, for example, on the desired volume of the sample chamber **105**. Further, in some embodiments the bottom **126** may be substantially transparent and may include any desired curvature so that the bottom **126** may serve as a lens to allow optical instruments to carry out optical measurements or obtain readings from inside the sample chamber **105**.

The end **124** includes threads **128** formed therein for matingly engaging the top member **104** as described below. While the threads **128** are shown as external threads **128**, in some embodiments the threads **128** may be implemented as internal threads **128**. Additionally, in some embodiments the threads **128** can be omitted. Further, in some embodiments any other suitable structures of devices may be used to engage or couple the lid member **104** and the base member **102** to one another, such as press-fittings, lips, flanges, snap-in features, gaskets, sleeves, clamps, or combinations thereof.

The sidewall **108** further includes one or more ports **130** formed therein. The ports **130** are in fluid communication with the sample chamber **105** and may include threaded portions **132** configured to be coupled with any desired coupling, such as a valve, cap, seal, or sensor fitting, examples of which are described with reference to FIGS. **8**A-**8**F below. It is to be understood that any desired number of ports **130** may be implemented in some embodiments, such as one, three, four, or more than four ports **130**. Further, in some embodiments, the ports **130** may be omitted, or one or more ports **130** may be in fluid communication with the sample chamber **105** via any desired location along the sidewall **108**, the base member **102** and/or the lid member **104**. In some embodiments one or more ports **130** may protrude or may be level with the sidewall **108**. For example, a top port **130** (e.g., fluidly coupled with a headspace above a level of a sample inside the sample chamber **105**) may be used to extract a supernatant or gas-chromatograph aliquot, a mid-height port **130** (e.g., fluidly coupled with the sample chamber **105** so as to be submerged or at least partially below a level of a sample in the sample chamber **105**) may be used for extracting a volume of sample, and a bottom port **130** (e.g., fluidly coupled with the sample chamber **105** at or below the level of the bottom **126**) may be used as a drain.

The lid member **104** may be implemented similarly to the base member **102** and includes a lid flange **134** and a sidewall **136**. The lid flange **134** has surfaces **138** and **140** and sides **142***a-d* intersecting with one another. The lid flange **134** further includes openings **144***a-d* formed therein. In some embodiments, the lid member **104** may include a transparent portion such that the sample chamber **105** is observable (e.g., via an optical instrument), while in some embodiments, the lid member **104** may be opaque.

The sides **142***a-d* may include notches **146** formed therein. The notches **146** may be implemented similarly to the notches **122** and are configured to allow easy access to the ports **130** from the direction of the lid member **102** as will be appreciated by persons of ordinary skill in the art having the benefit of the instant disclosure. In some embodiments, the notches **146** may abut or intersect with one or more of the openings **144***a-d* and/or may abut or intersect the sidewall **136**. Any desired number of sides **142***a-d* may be implemented with the inventive concepts disclosed herein, such as one side **142**, two sides **142**, three sides **142**, or more than four sides **142**.

The openings **144***a-d* may be configured to matingly (e.g., slidably or removably) receive the attachment protrusions **118***a-d* of the base flange **106** therein, and may include notches **150** formed therein and configured to matingly receive (e.g., removably or slidably) the lateral portion **120** of the attachment portions **118***a-d* therein, as will be appreciated by persons of ordinary skill in the art having the benefit of the instant disclosure. It is to be understood that any desired openings **144***a-d* may be implemented such as a single opening **144**, two openings **144**, three openings **144**, or more than four openings **144** in some embodiments. Further, in some embodiments, the openings **144***a-d* may be omitted. In some embodiments, the openings may be separated at a distance from the sides **142***a-d* and the sidewall **136**, while in some embodiments one or more of the openings **144***a-d* may abut or intersect one or more of the sides **142***a-d* and/or the sidewall **136**.

The sidewall **136** may be implemented similarly to the sidewall **108** and extends from the surface **138** at a distance from the sides **142***a-n* and/or from the openings **144***a-d* such that the openings **144***a-d* are positioned between the sidewall **136** and the sides **144***a-d*. The sidewall **136** includes a bottom **152** and end **154** including threads **156** configured to matingly engage the threads **128** of the sidewall **108** such that the sidewalls **108** and **136** cooperate to define the sample chamber **105** and such that the surface **112** of the base flange **106** and the surface **138** of the lid flange **134** are in an opposing spaced-apart relationship with one another. The sidewall **136** is engageable with the sidewall **108** in a substantially fluid-impermeable manner, such that the sample chamber **105** is substantially fluidly sealed or fluid-impermeable. Further, in some embodiments, the sidewall **136** is engageable with the sidewall **108** such that the sample chamber **105** is gas-impermeable and/or can maintain or withstand a predetermined amount of pressure or vacuum.

In some embodiments, gaskets, seals, sleeves, sealant tape or sealant materials, or any other desired devices or material may be implemented with the ends **124** and **154** and/or with the threads **128** and/or **156** so as to provide a substantially gas-impermeable and/or a substantially fluid-impermeable engagement of the sidewalls **108** and **136** with one another. Further, in some embodiments, the sidewall **136** and the sidewall **108** may be formed as a unitary component, or may be engageable with one another in any desired substantially fluid- and/or gas-impermeable manner, such as via welds, seams, joints, adhesives, ultrasonic welds, clamps, or combinations thereof.

Referring now to FIG. **7**, shown therein is a stack **158** including sample vessel assemblies **100** and **100***a* stacked onto one another such that the protrusions **118***a-d* of the sample vessel assembly **100** are matingly received in the openings **144***a-d* of the sample vessel assembly **100***a* and/or such that the lateral portions **120** of the sample vessel assembly **100** are matingly received in the notches **150** of the sample vessel assembly **100***a*, so that the surface **110** of the base flange **106** is positioned adjacent to or in contact with the surface **138** of the lid flange **134**. In some exemplary embodiments, the openings **116***a-d* may be substantially aligned with the openings **144***a-d*, or the openings **116***a-d* and the openings **144***a-d* may be offset relative to one another. Any desired number of sample vessel assemblies **100** may be stacked in similar manner, such as three, four, five, or more than five sample vessel assemblies **100**. Seal caps **160** are shown as being coupled with the threaded portions **132** of the ports **130** of the sample vessel assembly **100***a* so as to close the ports **130** in a substantially fluid-impermeable manner. The stack **158** may be used to transport the sample vessel assemblies **100** and/or to store sample vessel assemblies **100** short-term or long-term.

Referring now to FIGS. **8**A-**8**F, shown therein are examples of couplings such as valves, seals, caps, connectors, couplings, or sensor fittings that may be implemented with one or more ports **130** of sample vessel assemblies **100** according to embodiments of the inventive concepts disclosed herein.

As shown in FIG. **8**A, in some embodiments a seal cap **160** may be implemented with a port **130** of a sample vessel assembly **100**. The seal cap **160** may be implemented in some embodiments by being threadingly engaged with the threaded portion **132** of one or more ports **130** to lock, seal, or close the port **130**. The seal cap **160** may be coupled with the port **130** via a pressure seal or lock in a substantially gas-impermeable and/or substantially fluid-impermeable manner. Further, the seal cap **160** may be configured to withstand a predetermined high-pressure or vacuum and may be transparent or opaque in some embodiments.

As shown in FIG. **8**B, in some embodiments a membrane **162** may be implemented with one or more of ports **130** of a sample vessel assembly **100** according to the inventive concepts disclosed herein. The membrane **162** may be coupled with the threaded portion **132** of one or more of the ports **130**, and includes a septum of rubber or other elastomeric material to allow for easy sub-sampling of gas, liquids, or solids (e.g., aliquot via a probe or syringe) from the sample chamber **105**. In some embodiments, the membrane **162** may be compression-fitted or otherwise engaged with the port **130**, and can include a sealed cap (e.g., similar to the seal cap **160**). The membrane **162** may be substantially gas-impermeable and/or substantially fluid-impermeable, and may be configured to withstand atmospheric or low pressure. Further, the membrane **162** may be positioned at any desired height along the sidewall **108**, or may be positioned on the lid member **104** in some embodiments.

As shown in FIG. **8**C, in some embodiments a sieve **164** may be implemented with a port **130** of a sample vessel assembly **100** according to the inventive concepts disclosed herein. The sieve **164** may be coupled with the threaded portion **132** of one or more ports **130**, or may be positioned under a seal cap **160** coupled with one or more ports **130** in some embodiments. The sieve **164** may be used to remove liquids and/or wash solids from the sample chamber **105**, and may be configured so as to keep predetermined size particulates inside the sample chamber **105**. The sieve **164** may be formed in the sidewall **108**, in the lid member **104**, or may be attachable to the end **124** of the sidewall **108** so as to extend across the width of the sample chamber **105** in some embodiments.

As shown in FIG. **8**D, in some embodiments a hose coupling **166** may be implemented with a port **130** of a sample vessel assembly **100** according to the inventive concepts disclosed herein. The hose coupling **166** may be threadingly or otherwise engaged with the threaded portion **132** and/or otherwise engaged with the port **130** and may be pressure-sealed or locked. The hose coupling **166** may be used to withdraw water, air, sample, or to drain the sample chamber **105** and may be configured to withstand any desired pressure including relatively high-pressures.

As shown in FIG. **8**E in some embodiments a valve coupling **168** may be implemented with a port **130** of a sample vessel assembly **100** according to the inventive concepts disclosed herein. The valve coupling **168** which may be implemented as a twist-on compression fitting or locking and may be a one-way valve coupling **168** (e.g., allowing flow or material in one direction and preventing flow of material in an opposite direction) or two-way valve coupling **168** (e.g., allowing bi-directional flow of material), and may be water or air tight. The valve coupling **168** may be used to withdraw and/or introduce water, air, solution, or to drain the sample chamber **105**, and can be configured to withstand high-pressures in some embodiments.

As shown in FIG. **8**F, in some embodiments a sensor fitting **170** may be implemented with a port **130** of a sample vessel assembly **100** according to the inventive concepts disclosed herein. The sensor fitting **170** may be coupled with the port **130**, and may be configured to interface with any desired sensor, probe, or device, such as temperature, pressure, chemical receptor-based sensors (e.g., configured so sense, detect, or measure C1-C10 hydrocarbon gas species, organic acids, inorganic compounds, including but not limited to: N_2, Ar, O_2, H_2O, He, H_2, sulfur-containing compounds such as SO_2, COS, CS_2, ethene, oxygen—ambient and/or dissolved, gas, or liquid-based probes, CO, CO_2, specific C1 species, pH of H+ probes), semi-permeable membrane extraction, mass spectroscopy, and combinations thereof. In some embodiments, the sensor fitting **170** may include one or more probes, detectors, or sensors which may be at least partially positioned inside the sample chamber **105** via the port **130**, such as by being submerged in or otherwise contacting a fluid or liquid sample in the sample chamber **105**, or by being position above a level or fluid or liquid sample in the sample chamber **105** (e.g., in a headspace above the sample), or combinations thereof.

Embodiments of sample vessel assemblies **100** according to the inventive concepts disclosed herein may be labeled, or otherwise marked or associated with an unique identifier (e.g., a bar code, a QR code, an RFID tag, visual or haptic markings) identifying one or more of: the sample vessel assembly **100**, a sample contained in the sample vessel assembly **100**, location and/or time the sample was obtained. Further, sample vessel assemblies **100** may be marked or otherwise associated with the identity of obtaining person, destination for the sample, special handling instructions, nature of the sample, requested tests, storage instructions, shipping instructions, or any other desired information pertinent to the sample vessel assembly **100** or to a volume of sample contained therein, or any other feature, attribute, or identifying information relating to a sample positioned in the sample chamber **105** of a sample vessel assembly **100**.

It is to be appreciated that sample vessel assemblies **100** according to the inventive concepts disclosed herein may be provided in one or more modular sizes, may include shallower, larger-diameter sample chambers **105**, deeper, narrower-diameter sample chambers **105**, or offset ports **130** and angled (e.g., about 90° or any desired angle) ports **130** which may be implemented as a single fill-size port **130**, for example.

In use, a user may introduce any desired volume, weight, or amount of sample in the sample chamber **105** of a sample vessel assembly **100** in any desired manner. In some embodiments, the user may disassemble the sample vessel assembly **100** by uncoupling or disengaging the base member **102** and the lid member **104** from one another, or may simply obtain a base member **102** where the sample vessel assembly **100** is shipped or provided to the user as a disassembled kit. The user may introduce any desired amount volume or weight of sample into the sample chamber **105** such as by placing the sample inside the sidewall **108**. The user may then assemble the sample vessel assembly **100** by engaging or coupling the lid member **104** with the base member **102**. In some embodiments, a volume, amount, or weight of a sample may be introduced into the sample chamber **105** via one or more of the ports **130** which may be sealed such as via a seal cap **160**, for example. The user may conveniently and easily access the one or more ports **130** from the direction of the base member **102** and/or from the direction of the lid member **104** via the notches **122** and **146**, respectively.

Once the base member **102** and the lid member **104** are engaged with one another in a fluidly-impermeable manner, and/or one the one or more ports **130** are closed or sealed, the user may associate any desired unique identifiers with the sample vessel assembly **100**, and may store, ship, or transport the sample vessel assembly **100** to any desired location for processing and/or storage. The user may stack any desired number of sample vessel assemblies **100** such as in a stack **158** as described above.

Referring now to FIG. **9**, in some embodiments, sample vessels assemblies **100** according to the inventive concepts disclosed herein may be implemented with an automated analysis system **180**. The automated analysis system **180** includes a controller **182**, one or more memory **184**, an input device **186**, and output device **188**, an I/O port **190**, and a sample analyzer **192**. The controller **182** may include at least one processor such as a digital signal processor, a single processor or multiple processors working together to execute the logic described herein. Exemplary embodiments of the controller **182** include a digital signal processor (DSP), a central processing unit (CPU), a field programmable gate array (FPGA), a microprocessor, a multi-core processor, and combinations thereof. The controller **182** is configured to bi-directionally communicate (e.g., exchanging data and or signals) with the memory **184** via a path **194** which may be implemented as a data bus. The controller is also capable of bi-directionally communicating with the sample analyzer **192** via path **194***a*, with the input device **186** via a path **194***b*, with the output device **188** via a path **194***c*, and with the I/O port **190** via a path **194***d*.

The memory **184** stores processor executable code and may be implemented as any desired non-transitory processor-readable medium, such as random access memory (RAM), a CD-ROM, a hard drive, a solid state drive, a flash drive, a memory card, a DVD-ROM, a floppy disk, an optical drive, and combinations thereof, for example. It is to be understood that while the memory **184** is shown located in the same physical location as the automated analysis system **180**, in some embodiments the memory **184** may be located remotely from the automated analysis system **180** and may communicate with the controller **182** via a network **198**. Additionally, in some embodiments more than one memory **184** may be implemented, with one or more memory **184** being located in the same physical location as the automated analysis system **180**, and one or more memory **184** being located in a remote physical location from the automated analysis system **180**. The physical location(s) of the memory **184** can be varied, and the memory **184** may be implemented as a "cloud memory," e.g., one or more memory **184** which is partially or completely based on or accessed using the network **198**.

The input device **186** transmits data to the controller **182**, and can be implemented as a keyboard, a mouse, a touchscreen, a camera, a cellular phone, a tablet, a smart phone, a PDA, a microphone, a network adapter, a QR code reader, a bar code reader, an optical imager, an RFID reader, or combinations thereof, for example. The input device **186** may be located in the same physical location as the automated analysis system **180**, or may be remotely located and/or partially or completely network-based.

The output device **188** transmits information from the controller **182** to a user, such that the information can be perceived by the user. For example, the output device **188** can be implemented as a server, a computer monitor, a cell phone, a tablet, a speaker, a website, a PDA, a fax, a printer, a projector, a laptop monitor, and combinations thereof. The output device **188** can be physically co-located with the automated analysis system **180**, or can be located remotely from the automated analysis system **180**, and may be partially or completely network based (e.g., a website). As used herein the term "user" is not limited to a human, and may comprise a human, a computer, a web server, a database, a host system, a smart phone, a tablet, and combinations thereof, for example.

The I/O port **190** may be implemented as any desired computer port such as an optical port, a wireless transceiver, an Ethernet port, a USB port, an HDMI port, and is configured to transmit one or more signals over the network **198** and/or to receive one or more signals from the network **198**.

The sample analyzer **192** may be operably coupled with one or more sample vessel assemblies **100** according to the inventive concepts disclosed herein and to carry out any desired test, measurement, reading, or analysis of one or more properties of a sample positioned in the sample chamber **105** of the sample vessel assembly **100** and to transmit one or more signals indicative of data, measurements, properties, attributes, or features of the analyzed sample to the controller **182**. In some embodiments, the sample analyzer **192** may include at least one processor coupled with a non-transitory processor-readable medium storing processor-executable code or instructions.

As will be appreciated by persons of ordinary skill in the art having the benefit of the instant disclosure, the sample analyzer **192** may be implemented as any desired manual or automated device or instrument, such as a microscope, a chromatograph, an MRI imager, a spectrophotometer, a DNA sequencing device, Raman spectroscopy device, ultraviolet or visual spectroscopy device, temperature measuring device, or X-ray fluorescence device. In some embodiments, the sample analyzer **192** may include one or more manual or automated probes, manipulation arms, movable belts, trays, stages, or turntables, fluid pumps, gas pumps, robotic probes or arms configured to move a sample vessel assembly **100**, ovens, pressurized or fluid-impermeable chambers, or combinations thereof, for example. Any desired number of sample analyzers **192** may be implemented with the automated analysis system **180**, such as a single sample analyzer **192**, two or more sample analyzers **192**, or a plurality of sample analyzers **192**. Further, one or more sample analyzers **192** may be physically co-located with the automated analysis system **180**, and in some embodiments, one or more sample analyzers **192** may be remotely located from the automated analysis system **180** and may exchange signals and/or data with the automated analysis system **180** via the network **198**.

The network **198** permits bi-directional communication of information and/or data between the automated analysis system **180** and one or more remote devices such as a web server **200**, a computer **202**, and/or a mobile device **204** (e.g., a smartphone, or a tablet). The network **198** may interface with the I/O port **190** of the automated analysis system **180** in a variety of ways, such as by optical and/or electronic interfaces, and may use a plurality of network topographies and protocols, such as Ethernet, TC/IP, circuit switched paths, or combinations thereof, for example. For example, the network **198** can be implemented as the World Wide Web (or Internet), a local area network (LAN), a wide area network (WAN), a metropolitan network, a wireless network, a cellular network, a GSM-network, a CDMA network, a 3G network, a 4G network, a satellite network, a radio network, an optical network, a cable network, a public switched telephone network, an Ethernet network, and combinations thereof, and may use a variety of network protocols to permit bi-directional interface and communication of data and/or information between the automated analysis system **180** and the one or more remote devices or processors. The automated analysis system **180** may be deployed in the field (e.g., installed locally or as a mobile laboratory vehicle), or may be deployed in a central location where field or other samples are received and processed

Referring now to FIG. **10**, an embodiment of a method of using a sample vessel assembly **100** with the automated analysis system **180** is shown therein. Generally, one or a plurality of sample vessels assemblies **100** (**100***a*-**100***n*) are used to collect one or more samples, manually or mechanically as described above. One or more sample vessel assemblies **100** are added manually or mechanically to the sample analyzer **192** of the automated analysis system **180**.

The controller **182** may provide one or more control or drive signals to the sample analyzer **192** to cause the sample analyzer **192** to obtain a unique identifier of the sample vessel assembly **100** and/or the sample in the sample chamber **105**, such as by scanning or otherwise reading a unique identifier of the sample vessel assembly **100**, which may be implemented as a label, a sample vessel number, a bar or QR code, an RFID tag, or the sample may be manually identified by a user providing input to the automated analysis system **180** (e.g., via the input device **186**).

The controller **182** and/or the sample analyzer **192** may carry out any desired calibration steps, which may vary based on the type of sample vessel assembly **100**, the type of sample, or the type of sample analysis desired, for example.

The controller **182** may initiate sample preparation by the sample analyzer **192** via any desired method. For example, the sample may be heated in an oven or a dryer, a volume of supernatant may be eluted or titrated, analyte may be withdrawn, a solvent or other compound may be added to the sample such as pentane, toluene, acetone, alcohols, or any other desired chemical, or combinations thereof. Further, the sample may be mechanically processed such as by crushing, shaking, grinding, homogenizing, or sonification, or combinations thereof.

The mass, volume, temperature, pressure, dissolved gasses, pH, or any other desired property, component, feature, or attribute of the sample may be measured by the sample analyzer **192** using any desired method such as photography, microscopy, ultraviolet or visible, infra-red, Fourier transform infrared spectroscopy, ion spectrum gas chromatography or mass spectroscopy, gas sorption, nuclear magnetic resonance, pressure-porosity, conductivity, or combinations thereof. The sample analyzer **192** may transmit one or more signals to the controller **182** indicative of any of the properties, attributes, components, or features of the sample measured, read, or determined as described above.

The controller **182** may receive, collect, store, and interpret data indicative of properties of a sample in the sample chamber **105** of the sample vessel assembly **100** in any desired manner, such as by storing raw or processed data in the memory **184** and/or by processing data by executing processor-executable code stored in the memory **184**. The controller **182** may also transmit one or more signals (e.g., via the I/O port **190**) indicative of sample data, including the unique identifier for the sample and/or the sample vessel assembly **100** to a remote device or processor such as the web server **200** (e.g., hosting a database), computer **202**, or mobile device **204**, over the network **198**, for example.

The processed sample vessel assembly **100** may be removed from the sample analyzer **192** of the automated analysis system **180** and may be stored as appropriate, or may be disposed of in accordance with any applicable disposal protocols or regulations.

The sample analyzer **192** and/or the automated analysis system **180** may be used to carry out any desired test of a sample positioned in the sample chamber **105** of a sample vessel assembly **100**. For example, the sample analyzer **192** may carry out visual or optical characterization of the sample, by measuring, detecting, calculating, or otherwise determining the lithology, color, porosity, iridescence, or particle size of the sample. Further, the sample analyzer **192** may carry out microscopy, photography UV and/or visual specophotometry with the sample. In some embodiments, the sample analyzer and/or the controller **182** may execute software or processor-executable code to analyze microscopic and macroscopic photography (e.g., average color values, point distribution, particle size, etc.) of the sample. Further, in some embodiments the sample analyzer **192** may carry out physical characterization of the sample, such as measuring dissolved oxygen and/or viscosity of the sample. In some embodiments, the sample analyzer and/or the controller may conduct analytical characterization of the sample, such as via infra-red spectroscopy, Raman spectroscopy, Gas Chromatography, Gas Chromatography—mass spectroscopy, high-pressure liquid chromatography, nuclear magnetic resonance, Fourier transform infrared spectroscopy, ion spectroscopy etc. Further, in some embodiments the sample analyzer **192** may carry out total organic carbon analysis by acidization, or may carry out Fischer Assay, X-ray diffraction, X-ray crystallography, X-ray fluorescence, Wavelength-dispersive X-ray spectroscopy, energy-dispersive X-ray spectroscopy, gas sorption, pyconometry, porosimetry, or any other desired test or analytical method.

Further, in some embodiments the memory **184** of the automated analysis system **180** may be provided with any desired algorithm to trigger procedural modifications (what analysis or step to carry out next) based on results, signals, or data provided to the controller **182** by the sample analyzer **192**. Further, multiple sample vessel assemblies **100** may be preconfigured for varied testing regimens or sequences such as taking any desired number (e.g., 1-12) samples rapid-fire, then sending each sample to a different sample analyzer **192** and/or a different automated analysis system **180** for preparation and analysis.

From the above description, it is clear that the inventive concepts disclosed and claimed herein are well adapted to carry out the objects and to attain the advantages mentioned herein, as well as those inherent in the instant inventive concepts. While exemplary embodiments of the inventive concepts have been described for purposes of this disclosure, it will be understood that numerous changes may be made which will readily suggest themselves to those skilled in the art and which are accomplished within the spirit of the inventive concepts disclosed and/or defined in the appended claims.

What is claimed is:

1. A sample vessel assembly, comprising:

a base member including:

a base flange having first and second opposing surfaces and first and second sides intersecting with one another; and

a first sidewall extending from the first surface at a distance from the first and second sides; and

a lid member, including:

a lid flange having third and fourth opposing surfaces and third and fourth sides intersecting with one another; and

a second sidewall extending from the third surface at a distance from the third and fourth sides, the second sidewall engageable with the first sidewall such that the first surface of the base flange and the third surface of the lid flange are in an opposing spaced-apart relationship with one another and such that the first and second sidewalls cooperate with one another to define a sample chamber,

wherein the base flange further includes at least one opening formed therein and at least one attachment protrusion extending from the second surface adjacent to the at least one opening.

2. The sample vessel assembly of claim **1**, wherein the first sidewall and the second sidewall are threadingly engageable with one another.

3. The sample vessel assembly of claim **1**, wherein the lid flange further includes at least one opening for matingly receiving the attachment protrusion therein of a base flange of another vessel assembly.

4. A sample vessel assembly, comprising:

a base member including:

a base flange having first and second opposing surfaces and first and second sides intersecting with one another; and

a first sidewall extending from the first surface at a distance from the first and second sides; and

a lid member, including:

a lid flange having third and fourth opposing surfaces and third and fourth sides intersecting with one another; and

a second sidewall extending from the third surface at a distance from the third and fourth sides, the second sidewall engageable with the first sidewall such that the first surface of the base flange and the third surface of the lid flange are in an opposing spaced-apart relationship with one another and such that the first and second sidewalls cooperate with one another to define a sample chamber,

wherein the first sidewall includes at least one port fluidly coupled with the sample chamber.

5. The sample vessel assembly of claim **1**, wherein the base flange is substantially square.

6. The sample vessel assembly of claim **5**, wherein the lid flange is substantially square.

7. A sample vessel assembly, comprising:

a base member including:

a base flange having first and second opposing surfaces and first and second sides intersecting with one another; and

a first sidewall extending from the first surface at a distance from the first and second sides; and

a lid member, including:

a lid flange having third and fourth opposing surfaces and third and fourth sides intersecting with one another; and

a second sidewall extending from the third surface at a distance from the third and fourth sides, the second sidewall engageable with the first sidewall such that the first surface of the base flange and the third surface of the lid flange are in an opposing spaced-apart relationship with one another and such that the first and second sidewalls cooperate with one another to define a sample chamber,

wherein the base flange further includes at least one opening formed therein, the at least one opening separated a first distance from the first and second sides and a second distance from the first sidewall.

8. A sample vessel assembly, comprising:

a base member including:

a base flange having first and second opposing surfaces and first and second sides intersecting with one another; and

a first sidewall extending from the first surface at a distance from the first and second sides; and

a lid member, including:

a lid flange having third and fourth opposing surfaces and third and fourth sides intersecting with one another; and

a second sidewall extending from the third surface at a distance from the third and fourth sides, the second sidewall engageable with the first sidewall such that the first surface of the base flange and the third surface of the lid flange are in an opposing spaced-apart relationship with one another and such that the first and second sidewalls cooperate with one another to define a sample chamber,

wherein the first sidewall further includes at least one port fluidly coupled with the sample chamber, and wherein at least one of the first and second sides further includes at least one notch formed therein and positioned substantially centered relative to the at least one port.

9. The sample vessel assembly of claim **8**, wherein the at least one notch is at least one first notch, and wherein at least one of the third and fourth sides includes at least one second notch substantially aligned with the at least one first notch.

10. A sample vessel assembly, comprising:

at least two sample vessel assemblies attached on one another, each of the sample vessels comprising:

a base member including:

a base flange having first and second opposing surfaces and first and second sides intersecting with one another; and

a first sidewall extending from the first surface at a distance from the first and second sides; and

a lid member, including:

a lid flange having third and fourth opposing surfaces and third and fourth sides intersecting with one another; and

a second sidewall extending from the third surface at a distance from the third and fourth sides, the second sidewall engageable with the first sidewall such that the first surface of the base flange and the third surface of the lid flange are in an opposing spaced-apart relationship with one another and such that the first and second sidewalls cooperate with one another to define a sample chamber,

wherein each of the base flanges further includes at least one opening formed therein and at least one attachment protrusion extending from the second surface adjacent to the at least one opening.

11. The sample vessel assembly stack of claim **10**, wherein each of the lid flanges further includes at least one opening for matingly receiving the at least one attachment protrusion of the base flange of another sample vessel assembly.

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